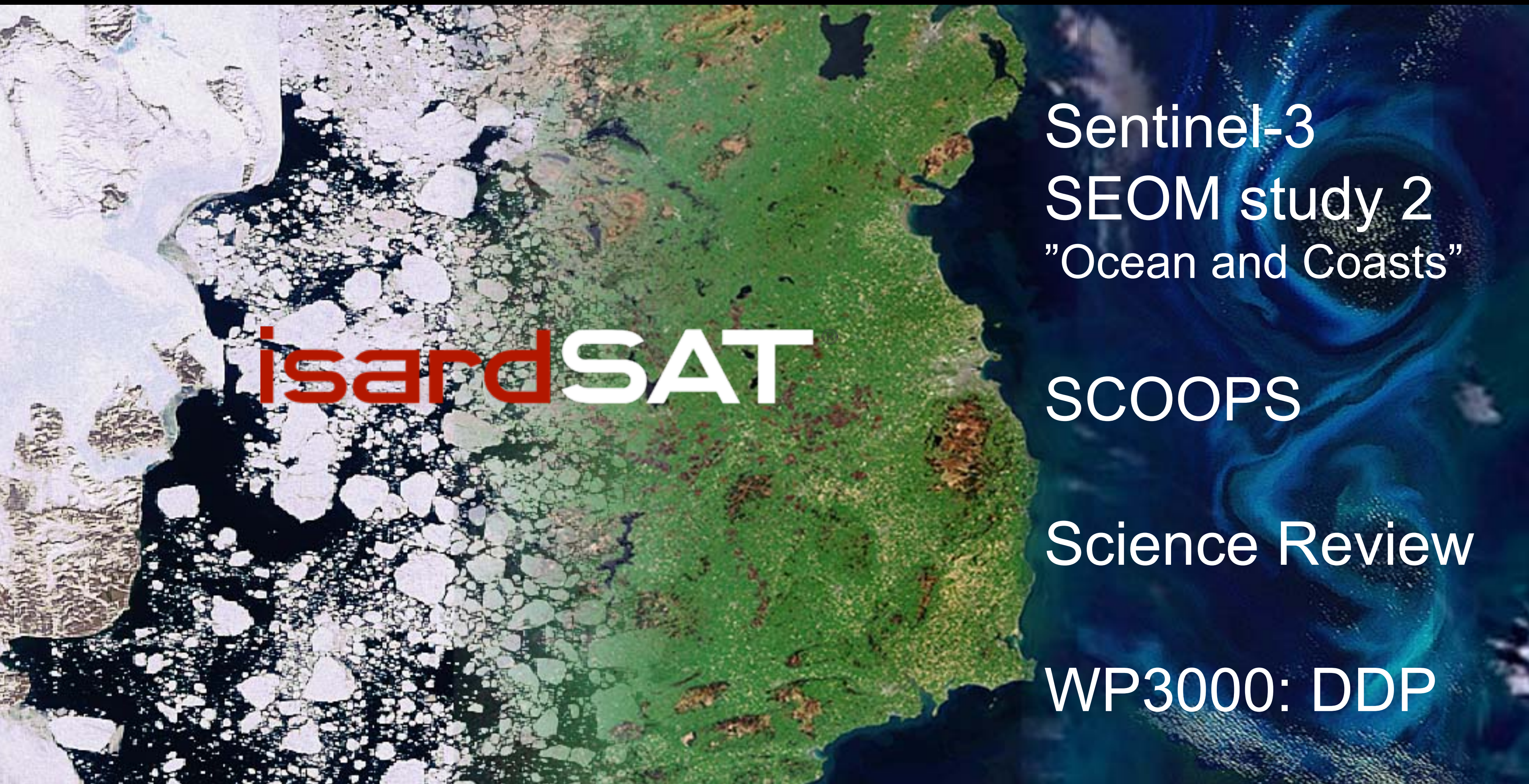


Sentinel-3 SEOM study 2

”Ocean and Coasts”

SCOOPS

Science Review

WP3000: DDP

Objectives of WP3000 – DDP development

- Implementing the initial processing scheme to produce L1B data from Cryosat-2 SAR C-FBR data, and generating the initial L1B test data sets for open ocean and coastal zone studies.
- Developing, testing and implementing modifications to the L1 processing.
- Implementing modifications to the processing scheme to produce L1B data, and generating L1B test data sets phase 2 of the open ocean and coastal zone.

DDP Development overview

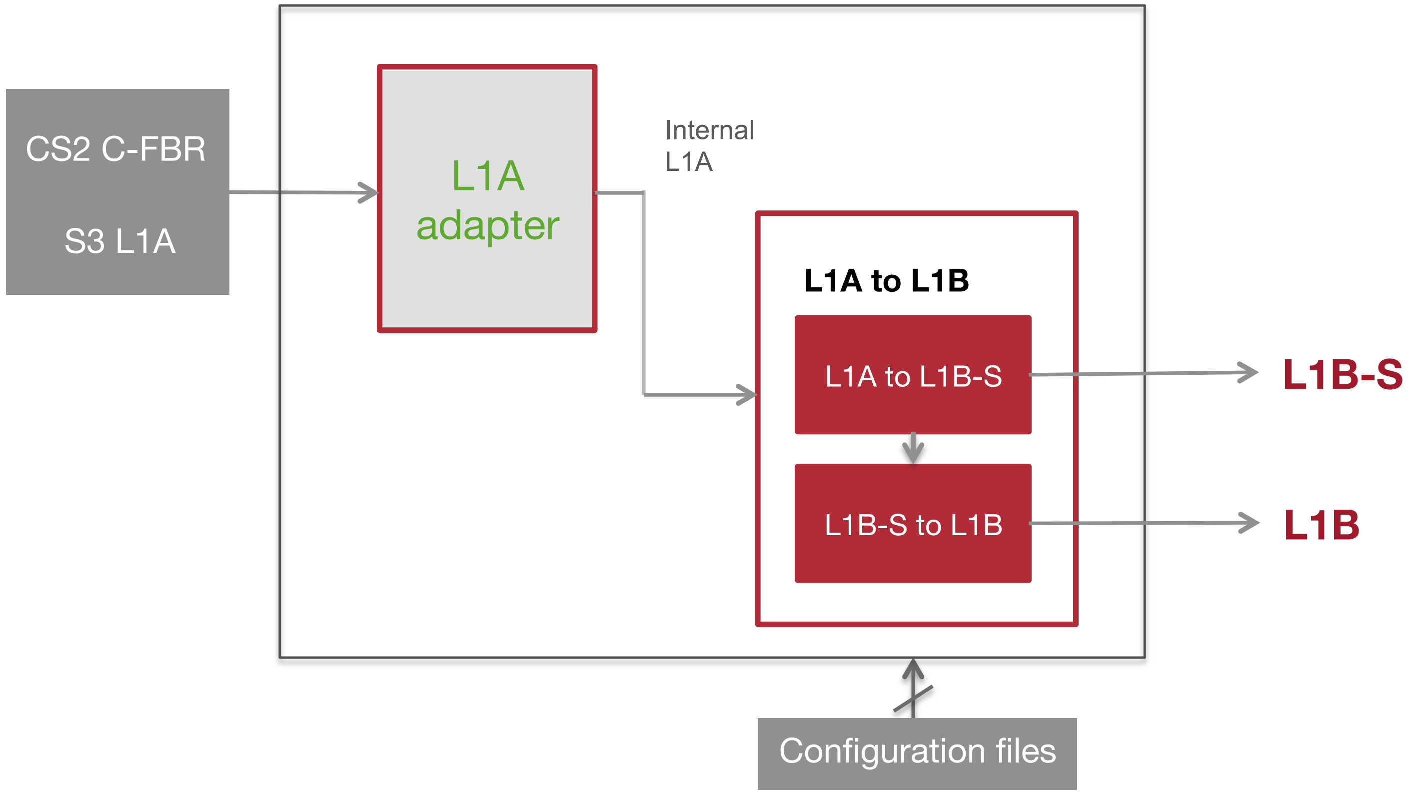
SCOOP Sentinel-3 L1 Delay-Doppler Processor (DDP) will be an **evolution** of isardSAT's existing DDPs:

- **Sentinel-6/Jason-CS P4 GPP** (under ESTEC/ESA contract)
- CryoSat-2 DDP (developed in-house)
- Sentinel-3 L0/L1 GPP (developed for ESA through CLS)

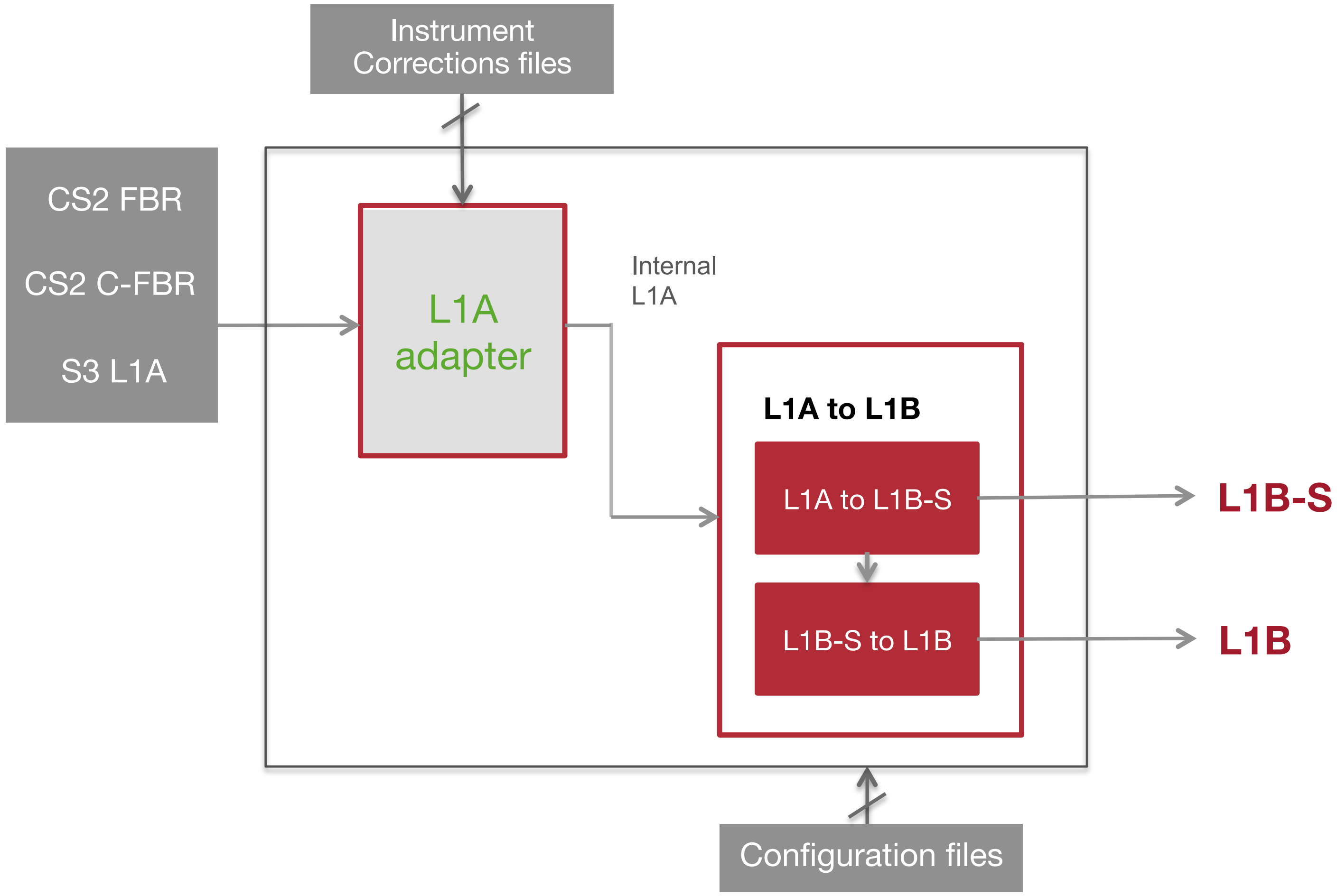
- The main processing stages of the Doppler-Delay processor (DDP) are:
  1. Surface locations, Final burst datation and Window delay
  2. Beam angles computation
  3. Azimuth processing (Delay-Doppler processing + Stacking)
  4. Geometry corrections
  5. Range compression
  6. Multi-looking
  7. Scaling factor computation (sigma-0 extraction)

- Details on the description and mathematical formulation of each of the processing stages in SCOOP ATBD (D1.3).

- DDP SW architecture (based on S6 L0/L1 GPP)

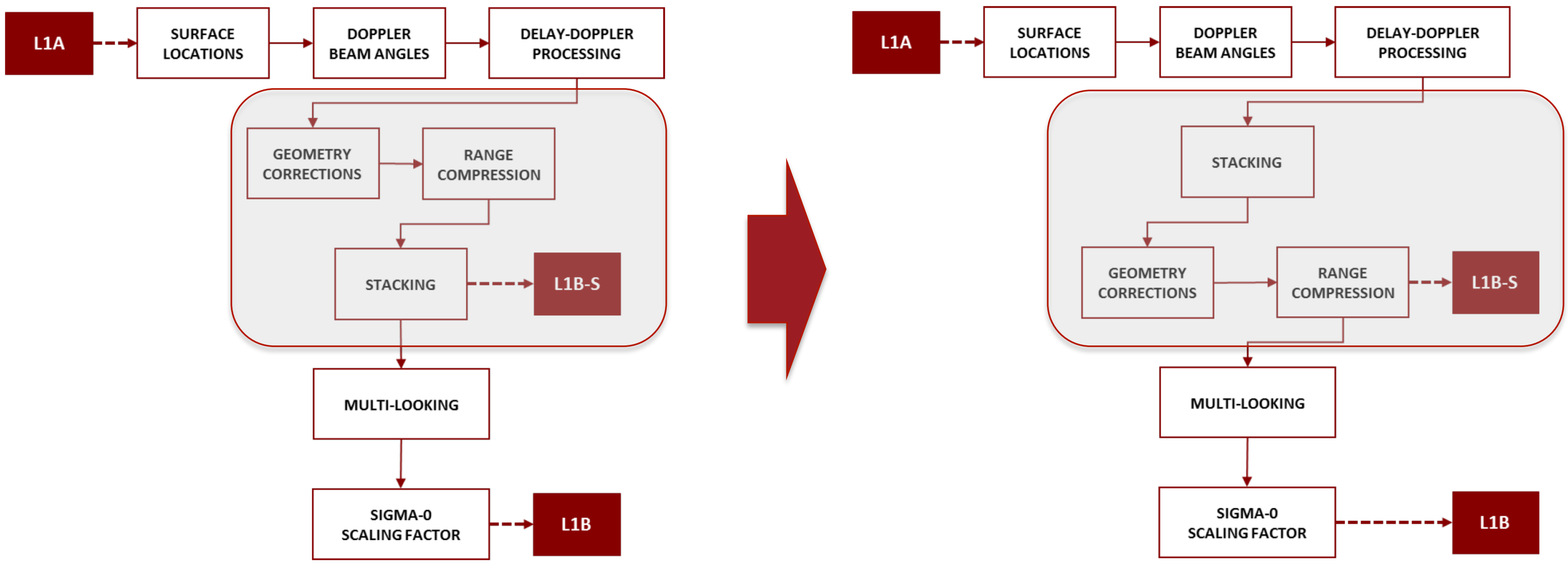


- DDP SW architecture (based on S6 L0/L1 GPP)



DDP Architecture

Change of architecture compared to previous alt. SAR L1b proc. (as for S6):



Will apply all corrections to surface-referenced echoes instead of satellite-referenced.

Helps validation & verification processes and incorporation of improvements in the stack. By itself shall not imply any improvement in performance.

Options on a DDP

GPP Processor Configuration			
Parameter	Type	Options	Applications
Burst azimuth windowing	Weighting	Deactivated /Boxcar, Hamming, Hanning	All
Surface focusing	Beam Pointing	Nominal / Surfaces forced by the user	Point Target, Inland waters
Azimuth processing method	Beam Pointing	Exact / Approximate	Point Target, Inland waters, Coastal
L1B-S and L1B range oversampling factor	Increase resolution	Deactivated / ZP = 2^n	Specular echoes
Stack masking	Cleaning	Deactivated / Defined by the user	Inland waters, Coastal
Antenna weighting	Weighting	Deactivated / Activated	All
Sigma-0 at stack level	Increase resolution	Deactivated / Activated	All
Multi-look zeros method	Weighting	Using / Not using zeros	All

Implementation language: Python

Already in isardSAT:

- C++ (Sentinel-3 and Sentinel-6)
- Matlab (CryoSat-2, Sentinel-3 and Sentinel-6).

Choosing one of these would save implementation time, but:

- C++ is not a high-level enough coding language for promoting the "hands on" the code for users to play with it
- MATLAB requires license.

Implementation language: Python

Python offers many advantages:

- Open source
- High-level coding language
- Eliminates overhead
  - Prevents ambiguity
  - More readable the code
- Low probability to have memory leaks
- Can incorporate C++ modules for hotspot optimisation

POCCD: Configuration file

Name	Description	Value
Burst azimuth windowing	Type of window applied to each burst before performing the azimuth FFT	0 None 1 Boxcar 2 Hamming 3 Hanning (4 Other)
Surface focusing	Option to move the surface locations	0 No 1 Only one given surface 2 A given surface and the following ones 3 A set of surfaces (If 3 then we need the name of the file with the given surfaces)
Azimuth processing method	Value that forces the precision of the Delay-Doppler process	0 Automatic 1 Approximate method 2 Exact method
Antenna weighting	Flag to compensate for the antenna pattern	0 No 1 Yes
L1B-S and L1B range oversampling factor	Number of zero-padding applied to the waveforms during the range compression process	2, 4, …, 1024, …
Stack masking	Flag to apply a mask to the stack in order to delete undesired phenomena	0 No 1 Yes
Multi-looking method	Average through all the samples or just consider the non-0 samples	0 All samples 1 Only non-0 samples
Sigma-0 at stack	Compute different Sigma-0 values within the stack or not (then, the computation is only made on averaged stacks, i.e., one value per L1B waveform)	0 No 1 Yes

POCCD: Configuration parameters

Name	Description	Value
Noise start sample	Start sample index for computing the waveform's noise	12*zp (zero-padding)
Noise stop sample	End sample index for computing the waveform's noise	16*zp
Noise floor	Maximum noise power allowed for a beam.	-
Noise top	Threshold that flags a beam if its integrated power is above this value.	3* Noise floor
Number of input points for surface interpolation	-	10
Number of output points of surface interpolation	-	Input points * 20
Smoothing factor for surface interpolation	-	0
Roughness threshold	Threshold that determines if a surface is rough or not. This is used to decide the type of interpolation is applied to the surface	10 meters
Reference beam	When aligning a stack, the beam that is taken as a reference. This could be the central beam, the beam with the highest integrated power, etc. TBD	0 Central 1 Maximum integrated power (2 Others)
Sub-stack size	When computing stack characteristics, number of stack integrated power that are averaged in order to smooth the fittings that are performed.	5

POCCD: Characterisation parameters

INSTRUMENT PARAMETERS	
Ku band frequency	13.575 GHz
Rx bandwidth	320 MHz
Rx pulse width	44.8 µs
Chirp slope sign	negative
SAR pulse repetition frequency	18181.818 Hz
Number of pulses in a BURST	64
Burst repetition interval	0.011693825 s
PTR 3dB width	2.801e-9 s
ANTENNA PARAMETERS	
Antenna 3dB aperture used to compute the doppler model	2D elliptic sinc function: teta3dB_X = 1.095 deg teta3dB_Y = 1.22 deg
Antenna gain at boresight	42.6 dB

- In order to produce a Sentinel-3 like TDS we will create a POCCD file Sentinel-3 like (parameters adjusted to S3).
- We also need to know the Configuration parameters (and any, if any, parameter that might be hard coded).
- And the Characterisation data.

isardSAT has delivered:

- DX.X: Technical Note on science review or state of the art.
- DX.X: Requirement Baseline
- D1.3: Algorithm Theoretical Basis Document (ATBD) → draft now and updated @ T0 + 14
- DX.X: POCCD

Issues

- Because of the heritage of our DD processor, we do not implement in two phases.
- Data volume is huge! 4 Tbytes.
- Processing volume and time do not allow to reprocess all the data in different configurations (S3 and +) !
- Processing time based on S6 requirements:

	CAL1 (1)	CAL1 (2)	CAL2	Processing time
CASE 1*	Applied	Not applied	Not applied	1 times real-time
CASE 2**	Applied	Applied	Applied	0.5 times real-time

Note that this processing time is to be achieve by the operational S6 GPP in 2018.

- Note that ACDC is not part of SCOOP project.

isardSAT

Thank You!

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Monica.Roca@isardSAT.co.uk

FBR (rough) data volume estimation

$$DV = N_{acq} \cdot T_{acq} / T_{rc} \cdot N_{brc} \cdot N_{pb} \cdot N_{s} \cdot 2 \cdot N_{bits}$$

Data Volume- Open ocean ROIs

ROI	Average volume per year (Gigabytes- GB)
CP40_002	**149,4**
CP40_003	**93**
SAR_Pico_00	**644,8**
AR2690_1	**37,16**
AN6524_1, AN6524_5 and AN6524_6	**257,4**
Agulhas (overlapping AR2677_1)	**167,65**
AR2690_2	**35,4**
Total	**1384,81**

Data Volume- Coastal zone ROIs

ROI	Average volume per year (Gigabytes- GB)
Flor_ST (overlapping AN2706_7)	**7**
CP4O_01	**146,6**
AmazonSAR	**26,8**
AN6524_1, AN6524_5 and AN6524_6	**194,1**
AN6524_4 (over North Sea)	**135,84**
Agulhas (overlapping AR2677_1)	**167,65**
ESurge_1	**50,2**
AN6531_4	**52,1**
Harvest	**19,6**
Total	**799,89**

Total amount (2-years period):

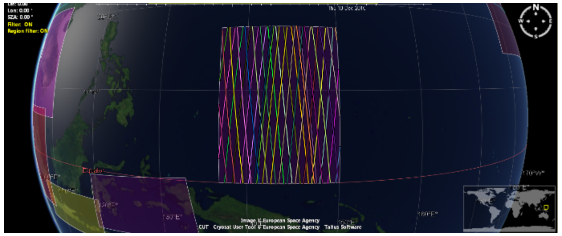
2.7 Tbytes (Open Ocean) & 1.6 Tbytes (Coastal Zones)

(*) Extrapolation of total volume amount from available data for April-October 2015 from CUT software

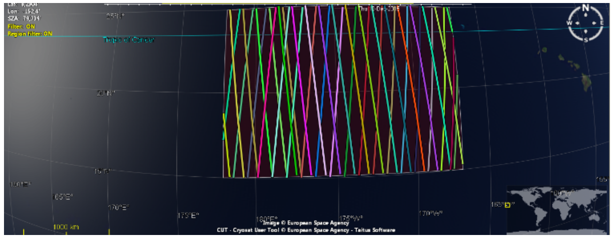
WP2000: Regions of Interest (I)

Open Ocean ROIs

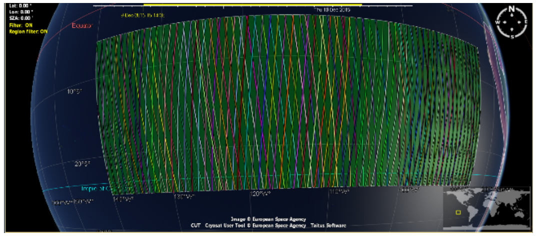
CP4O_002



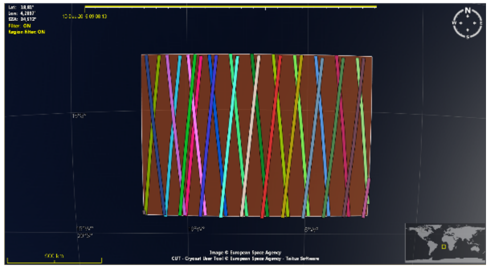
CP4O_003



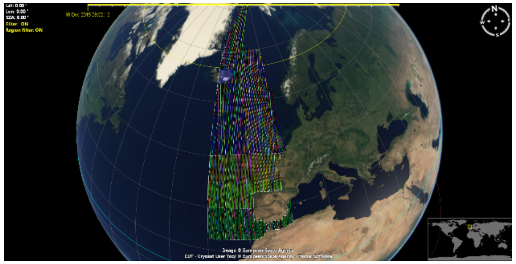
SAR_Pico_00



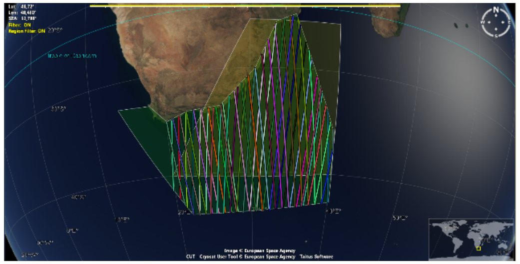
AR2690_1



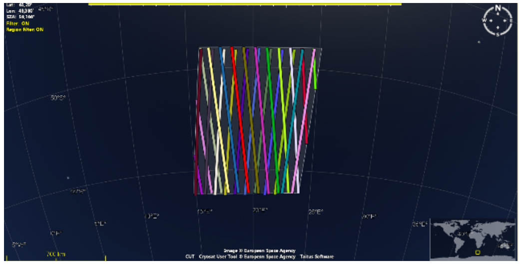
AN6524_1/5/6



AR2677_1

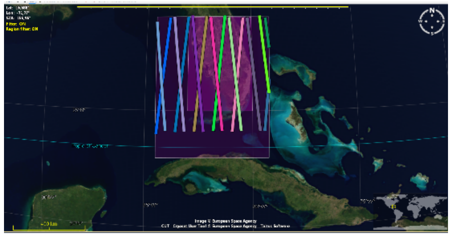


AR2690_2

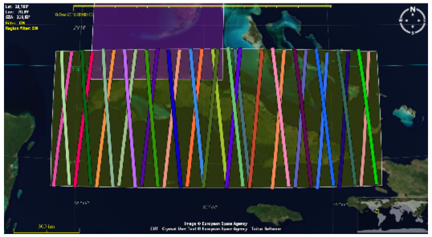


Open Ocean ROIs

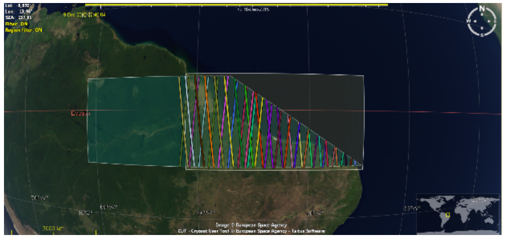
Flori_ST



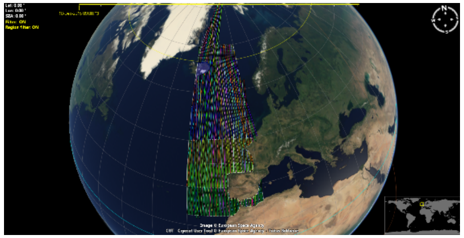
CP4O_01



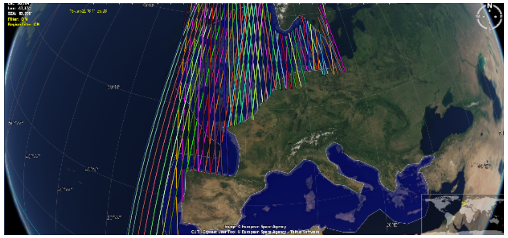
AmazoSAR



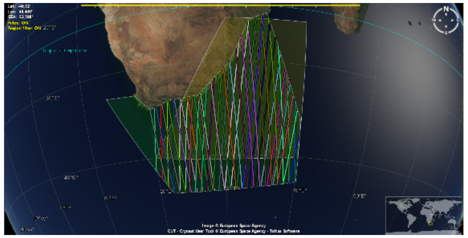
AN6524_1/5/6



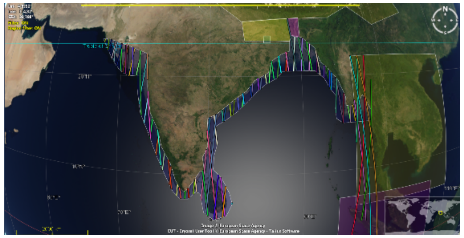
AN6524_1



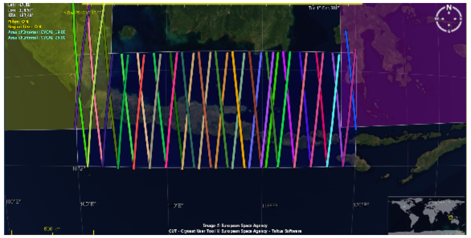
AR2677_1



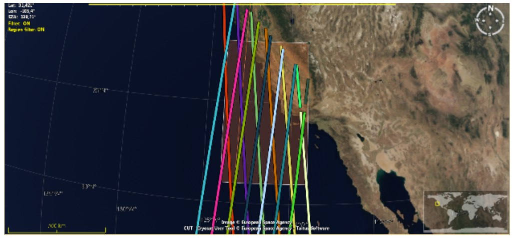
ESurge_1



AN6531_4



Harvest



Options on a DDP

GPP Processor Configuration			
Parameter	Type	Options	Applications
Burst azimuth windowing	Weighting	Deactivated /Boxcar, Hamming, Hanning	All
Surface focusing	Beam Pointing	Nominal / Surfaces forced by the user	Point Target, Inland waters
Azimuth processing method	Beam Pointing	Exact / Approximate	Point Target, Inland waters, Coastal
L1B-S and L1B range oversampling factor	Increase resolution	Deactivated / ZP = 2^n	Specular echoes
Stack masking	Cleaning	Deactivated / Defined by the user	Inland waters, Coastal
Antenna weighting	Weighting	Deactivated / Activated	All
Sigma-0 at stack level	Increase resolution	Deactivated / Activated	All
Multi-look zeros method	Weighting	Using / Not using zeros	All

Burst azimuth windowing

Before performing the azimuth FFT, the 64 pulses within a burst can be weighted.

Antenna weighting

If the antenna pattern is compensated in the L1B waveform, users can use the L1B data without having to assume a theoretical weighting in their retracking models.

All these weightings are provided in an input file, hence any weighting can be used.

Options on a DDP

GPP Processor Configuration			
Parameter	Type	Options	Applications
Burst azimuth windowing	Weighting	Deactivated /Boxcar, Hamming, Hanning	All
Surface focusing	Beam Pointing	Nominal / Surfaces forced by the user	Point Target, Inland waters
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Antenna weighting	Weighting	Deactivated / Activated	All
Sigma-0 at stack level	Increase resolution	Deactivated / Activated	All
Multi-look zeros method	Weighting	Using / Not using zeros	All

Surface focusing

The L1 processor performs a sampling of the surface according to Doppler resolution, which is inferred from the Doppler frequency definition:

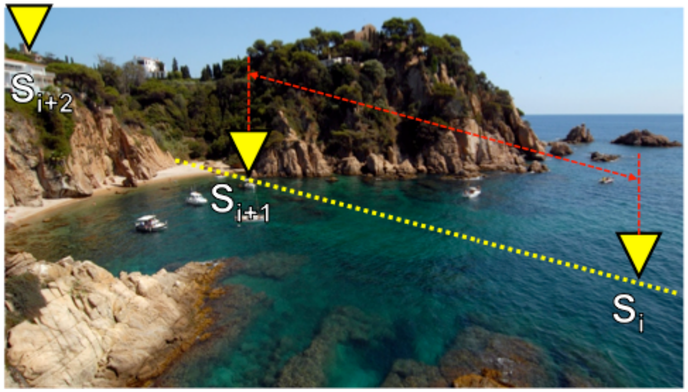
$$f_D = \frac{2\left|\vec{v}_s\right| \cdot \sin\theta}{\lambda} \quad (\mathrm{Hz})$$

But it can be modified.

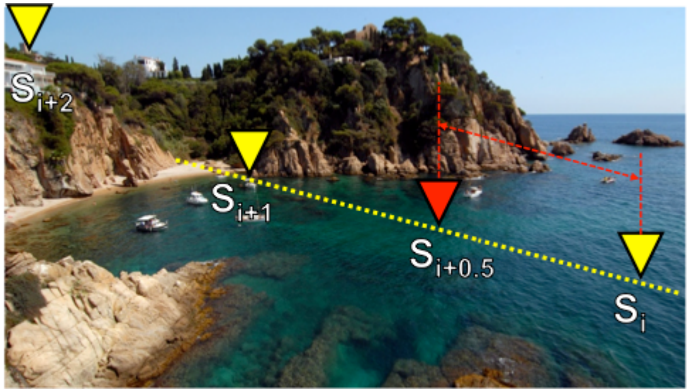
This is useful for special scenarios and/or targets such as coast.

Surface focusing

Coast example



With this scenario, echoes would be masked by land contamination, as the surface locations are very close to the shore.



We could then add a new surface location in order to get less contaminated echoes.

And even move the rest of the surfaces in order to maintain the spacing between them.

Options on a DDP

GPP Processor Configuration			
Parameter	Type	Options	Applications
Burst azimuth windowing	Weighting	Deactivated /Boxcar, Hamming, Hanning	All
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Antenna weighting	Weighting	Deactivated / Activated	All
Sigma-0 at stack level	Increase resolution	Deactivated / Activated	All
Multi-look zeros method	Weighting	Using / Not using zeros	All

Azimuth processing method

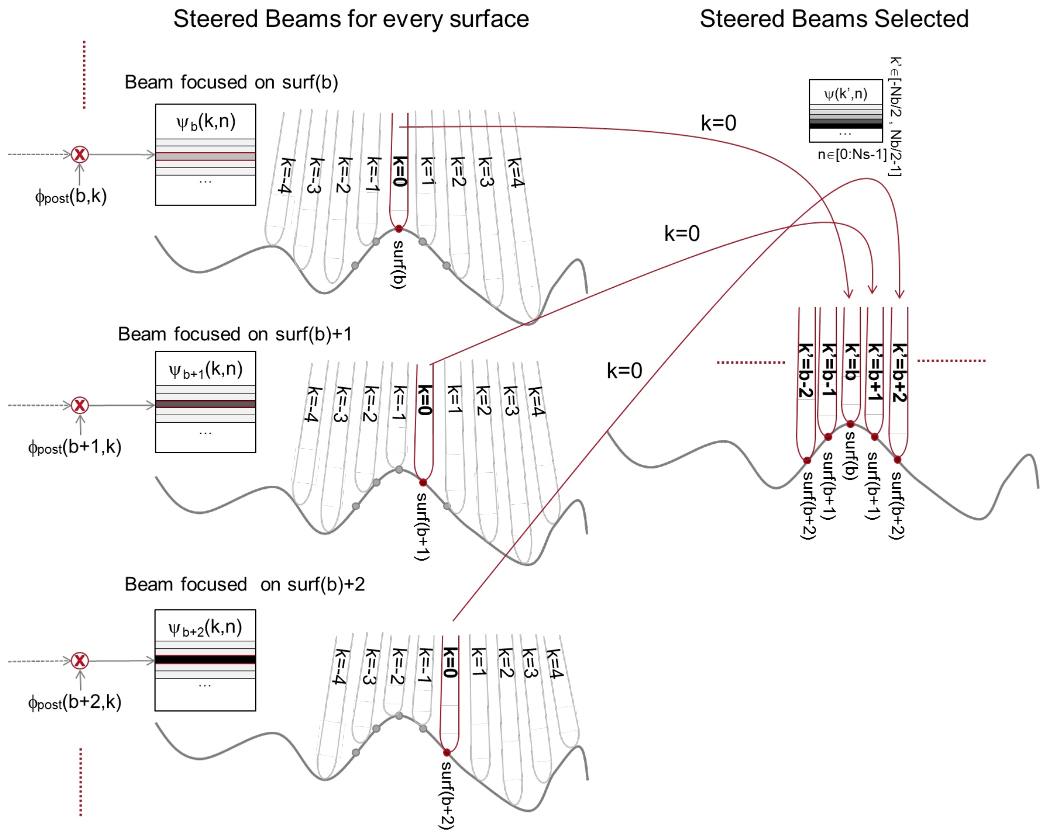
Doppler beams can be generated in two different ways depending on the variability of the surface.

With this switch, we choose whether the approximate or the exact method is used.

Then, L1 processor offers the possibility to choose among:

- Processing time (approximate method)
- Precision and accuracy (exact method)

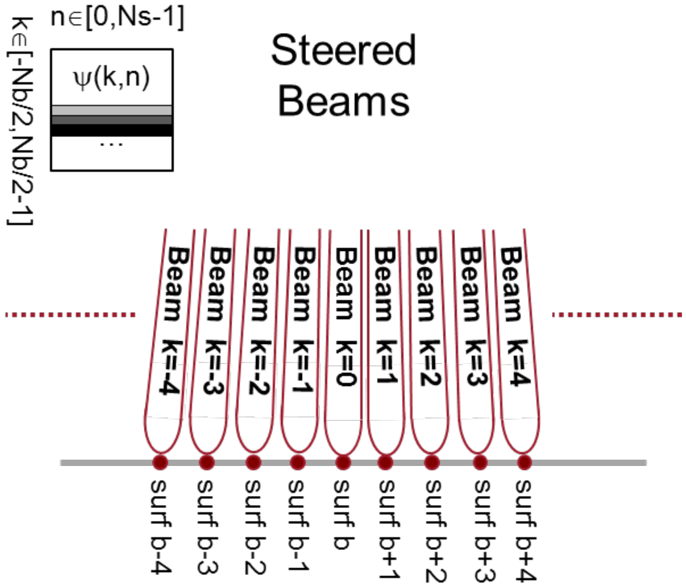
Exact method



For each burst, we need 64 azimuth FFTs:

1 azimuth FFT for each beam steered to a surface location.

Approximate method



For each burst, only 1 azimuth FFT is needed to steer the beams.

After the central beam is steered to surface location ‘b’, the other beams are equally distributed to the other surface locations.

For low variability surfaces, the beams are still “correctly” focused.

In high variability surfaces, the approximate method can create unevenly spaced projections on the ground.

Options on a DDP

GPP Processor Configuration			
Parameter	Type	Options	Applications
Burst azimuth windowing	Weighting	Deactivated /Boxcar, Hamming, Hanning	All
Surface focusing	Beam Pointing	Nominal / Surfaces forced by the user	Point Target, Inland waters
Azimuth processing method	Beam Pointing	Exact / Approximate	Point Target, Inland waters, Coastal
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Antenna weighting	Weighting	Deactivated / Activated	All
Sigma-0 at stack level	Increase resolution	Deactivated / Activated	All
Multi-look zeros method	Weighting	Using / Not using zeros	All

Range oversampling factor

Due to data rate volume limitations, the range compression FFT is normally performed with a zero-padding factor of 1 or 2.

An FFT with a zero-padding factor is theoretically the best possible interpolation, because it uses the phase information, as it is performed with I&Q signals before the waveform power computation.

This option gives the possibility to perform the range compression FFT with any zero-padding factor, which is a power of 2, both at stack level (L1B-S) and at Level 1B.

Options on a DDP

GPP Processor Configuration			
Parameter	Type	Options	Applications
Burst azimuth windowing	Weighting	Deactivated /Boxcar, Hamming, Hanning	All
Surface focusing	Beam Pointing	Nominal / Surfaces forced by the user	Point Target, Inland waters
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Antenna weighting	Weighting	Deactivated / Activated	All
Sigma-0 at stack level	Increase resolution	Deactivated / Activated	All
Multi-look zeros method	Weighting	Using / Not using zeros	All

Stack masking

Stacks can contain many undesired phenomena:

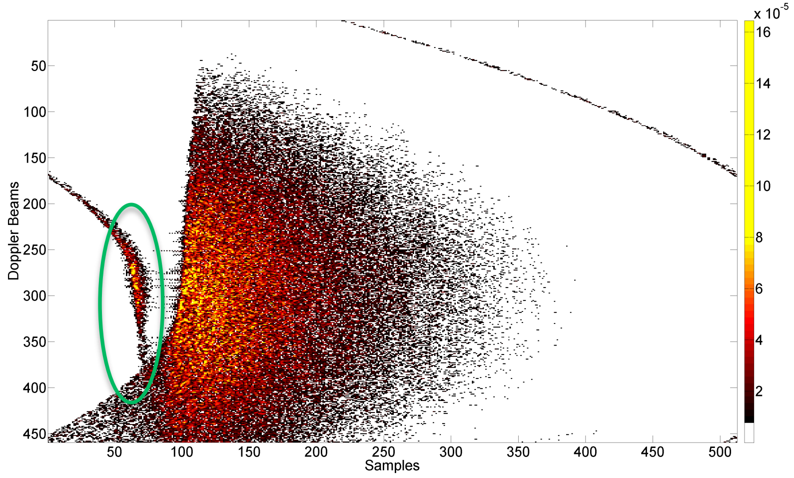
- Doppler ambiguities
- Land contamination
- Aliasing

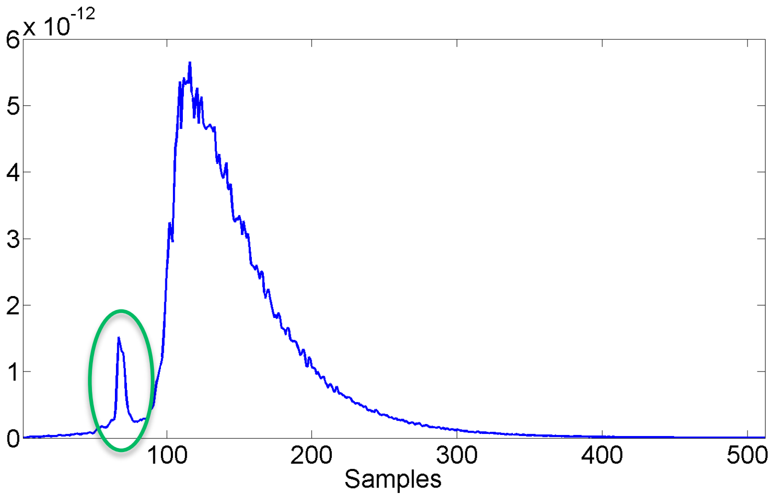
These interferences shall/can be removed in order to have cleaner stacks.

To solve these problems, different masks can be applied in both dimensions of the stack.

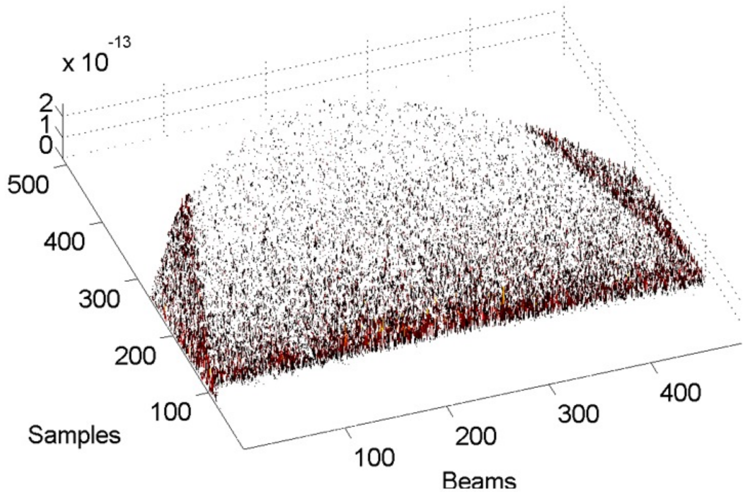
- Range
- Azimuth
- Range and azimuth

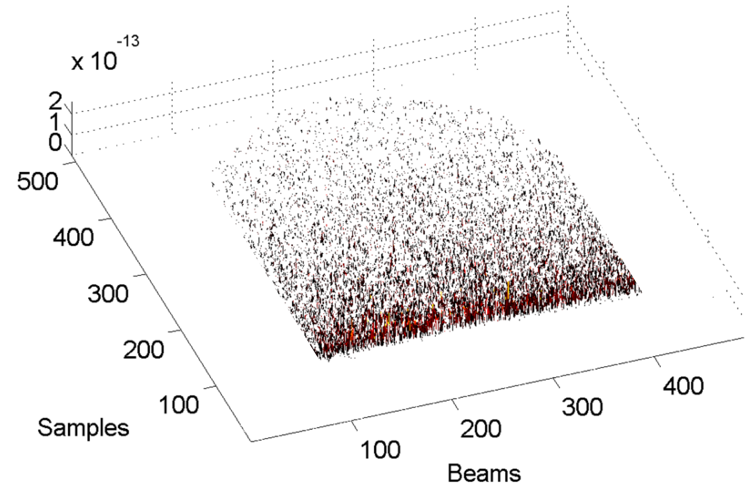
- Range


x 10^-5
16
14
12
10
8
6
4
2
50
100
150
200
250
300
350
400
450
Doppler Beams
50
100
150
200
250
300
350
400
450
500
Samples


x 10^-12
6
5
4
3
2
1
0
100
200
300
400
500
Samples

- Azimuth

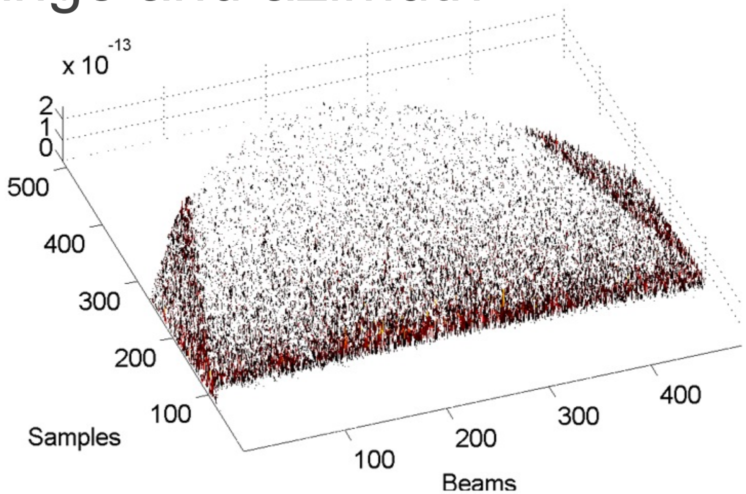


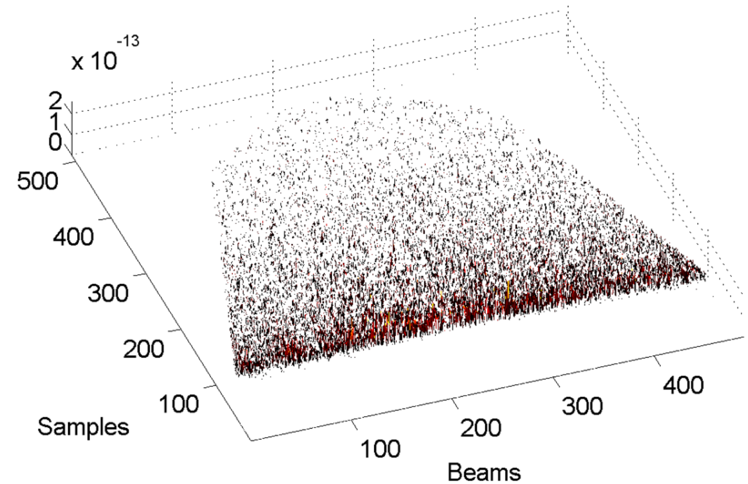


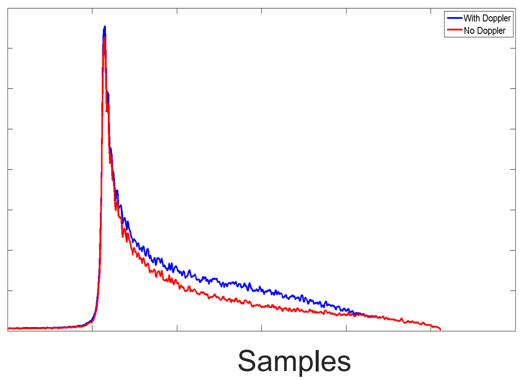
Less contributing beams → lower SNR

DDP Development

- Range and azimuth







Same contributing beams → maintains SNR

Best solution.
Only delete the affected samples → 2-D mask

Options on a DDP

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Parameter	Type	Options	Applications
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Antenna weighting	Weighting	Deactivated / Activated	All
Sigma-0 at stack level	Increase resolution	Deactivated / Activated	All
Multi-look zeros method	Weighting	Using / Not using zeros	All

Sigma-0 at stack level

Currently, the information on the Sigma-0 scaling factor provided in the L1B is an average of all the N scaling factors of the stack.

But each beam comes from a different pointing angle and, therefore, the geometry has changed and so has the attenuation of the antenna for each particular angle.

This option can be switched on in order to:

- Compare the results
- Understand the differences
- Provide more accurate Sigma-0 values

Options on a DDP

GPP Processor Configuration			
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Stack masking	Cleaning	Deactivated / Defined by the user	Inland waters, Coastal
Antenna weighting	Weighting	Deactivated / Activated	All
Sigma-0 at stack level	Increase resolution	Deactivated / Activated	All
Multi-look zeros method	Weighting	Using / Not using zeros	All

Multi-looked zeros method

After applying all the corrections in the L1B chain, some samples may have been forced to zero.

This option is used to decide if these samples are used in the multi-looking process or not.